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Ergonomic assessment of hospital bed moving using DHM Siemens JACK

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While the indirect and direct cost of occupational musculoskeletal disorders (MSD) causes a significant burden on the health system, lower back pain (LBP) is associated with a significant portion of MSD. In Australia, the highest prevalence of MSD exists for health care workers, such as nurses. The digital human model (DHM) Siemens JACK was used to investigate if hospital bed pushing, a simple task and hazard that is commonly associated with LBP, can be simulated and ergonomically assessed in a virtual environment. It was found that while JACK has implemented a range of common physical work assessment methods, the simulation of dynamic bed pushing remains a challenge due to the complex interface between the floor and wheels, which can only be insufficiently modelled.

Practitioner Summary: While the ergonomic DHM Siemens JACK has significantly evolved over time and now integrates complex ergonomic assessment methods, ergonomic assessment of a seemingly simple simulated task such as hospital bed pushing in a virtual environment still remains a challenge.

Keywords: digital human modelling, nursing, healthcare, pushing and pulling, manual materials handling

1. Introduction

The DHM system Siemens JACK (Siemens, Munich) was used to assess body strain of a selected workforce when handling a hospital bed (Figure 1).

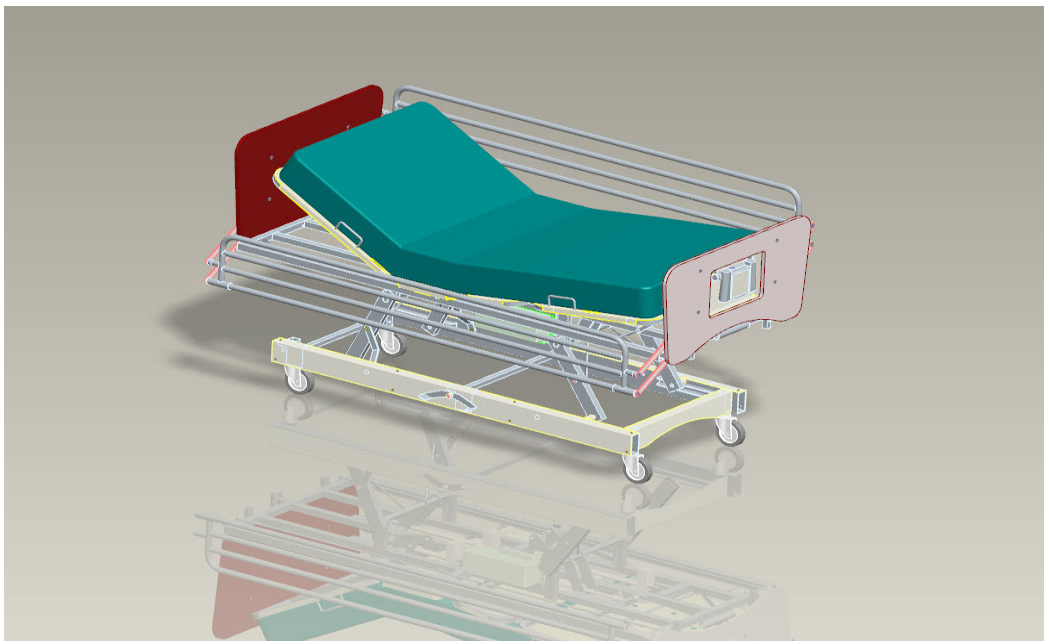


Figure1: Common hospital bed in a virtual environment.

Moving patients during care activities is a common task for nurses. Pushing and pulling hospital beds is a form of manual material handling that has been linked with a high risk for the development of musculoskeletal disorders. However, other than research into lifting tasks, the biomechanical or psychophysiological strain from pushing and pulling activities has been studied by far fewer researchers (Bhattacharya & McGlothlin, 2012).

Pushing and pulling in this work task includes dynamic work, as the lower extremities are involved in a walking movement. On the other hand, the upper part of the body is involved in static work with isometric muscular contractions, while controlling and steering the moving bed (Scott, Bennett, Todd, & Desai, 2011). Static load and effort reduces tissue blood supply through increased pressure on muscles, tissues, tendons and ligaments (Canadian Centre for Occupational Health and Safety, 2014). Consequently, this is an undesirable factor in a work system.

In many hospitals, and particularly for bariatric patients, two or three nurses jointly move a hospital bed, further complicating kinematic conditions. This represents a potential bottle neck for the complete work system and a high risk of developing MSDs for the workers. Moreover, when pushing and pulling, high risk shear force is acting on the spine. Shear forces on spinal discs are considered to have a one third lower tolerance limit compared to compression tolerance limits.

An ergonomic assessment is performed in a virtual environment allowing for variation of body proportions, in order to represent typical anthropometric conditions. Common ergonomic methods represented in the DHM system are selected for comparison, and the results from simulations through the different methods are compared. The case study introduces DHM for the assessment of a common ergonomic problem in healthcare systems, and exemplifies challenges in a common DHM system.

2. Methods

In order to analyse how anthropometric conditions influence ergonomic design and measurements, Siemens JACK was used. JACK is a powerful human simulation package that is able to recreate real workplace scenarios with dimensionally accurate objects and human figures (Siemens, 2014). Humanoids can be scaled and based on different anthropometric databases included in the JACK package. Table 1 lists the gender, height and weight of four custom mannequins in JACK, based on two databases (Peoplesize Australian population and a Chinese population). Figure 2 illustrates the corresponding human models in JACK.

Table 1. Anthropometric measures of two selected populations for modelling in JACK.

Manikin	Source	Description	Gender	Height (cm)	Weight (kg)
1	People size database (Australia)	95 th percentile (18-65 years-old)	Male	191.3	110
2	People size database (Australia)	5 th percentile (18-65 years-old)	Female	152.9	53
3	Chinese anthropometric data	95 th percentile (18-60 years-old)	Male	177.5	75
4	Chinese anthropometric data	5 th percentile (18-55 years-old)	Female	148.4	42

The AORN Ergonomic Tool 7, developed by Waters, Lloyd, Hernandez, and Nelson (2011) was used to provide input data, such as typical initial and sustained forces when pushing hospital beds. These data are required for JACK to conduct a meaningful biomechanical analysis.

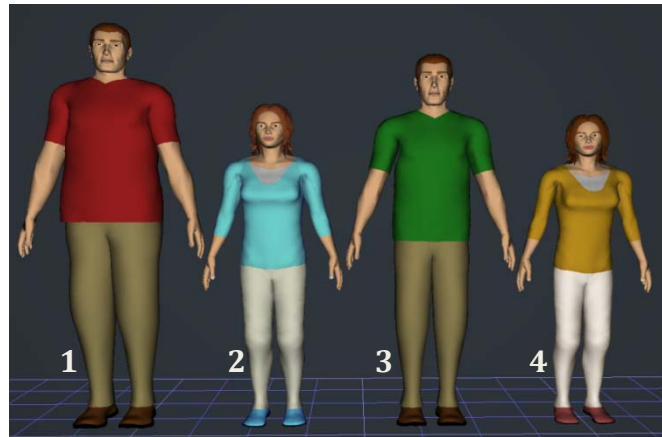


Figure 2. Custom human models in JACK, numbering see Table 1.

For an initial analysis, Ovako Working Posture Analysis (OWAS) and Rapid Upper Limb Assessment (RULA) were used. These are relatively simple methods that allow the analysis of posture comfort and give a score indicating the urgency of corrective measures or the level of risk. However both methods are static in nature and do not consider the dynamic nature of the task.

Eventually, a biomechanical analysis “low back analysis” was conducted in JACK. While the biomechanical analysis would principally allow for a dynamic analysis of forces and moments, the method is again restricted by a static posture.

3. Results

According to the force exerted by the person, different postures are adopted. The body posture is highly influenced by the handle height. When ergonomically designed, this handle height should be adjustable (to worker stature), however, in real hospital wards this is not always the case and awkward positions may be adopted when pushing the beds. Figure 3 shows diverse body postures that may be adopted according to worker stature.

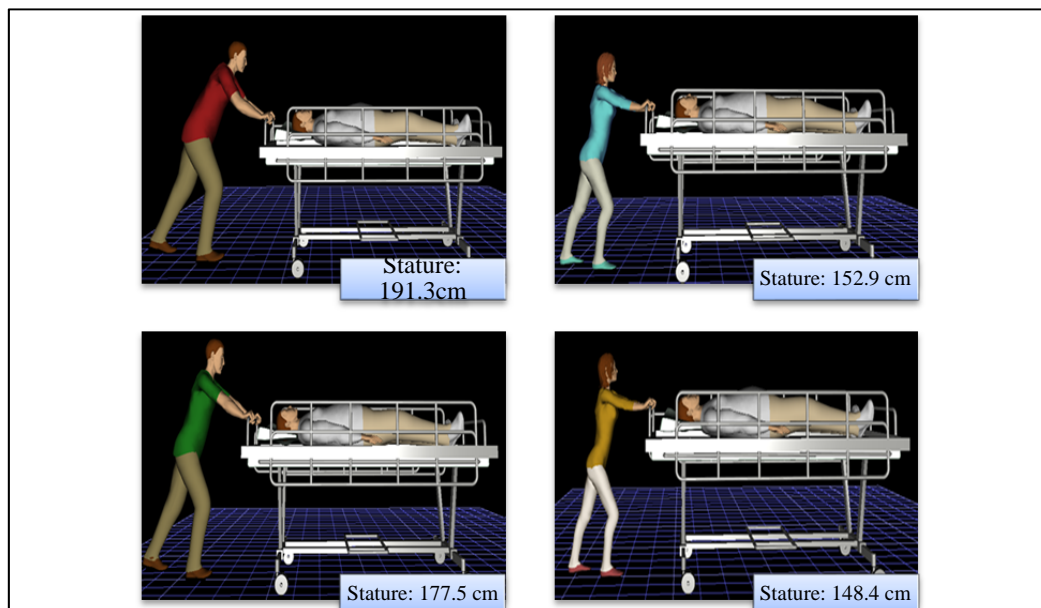


Figure 3. Working postures according to nurse stature.

Figure 4 illustrates the posture of a small female and results from OWAS and RULA analysis in JACK. A further limitation of the OWAS tool is that it only considers downward force components. In addition, neither tool provides quantitative data relating to biomechanical strain and injury risk; therefore further analysis is necessary.

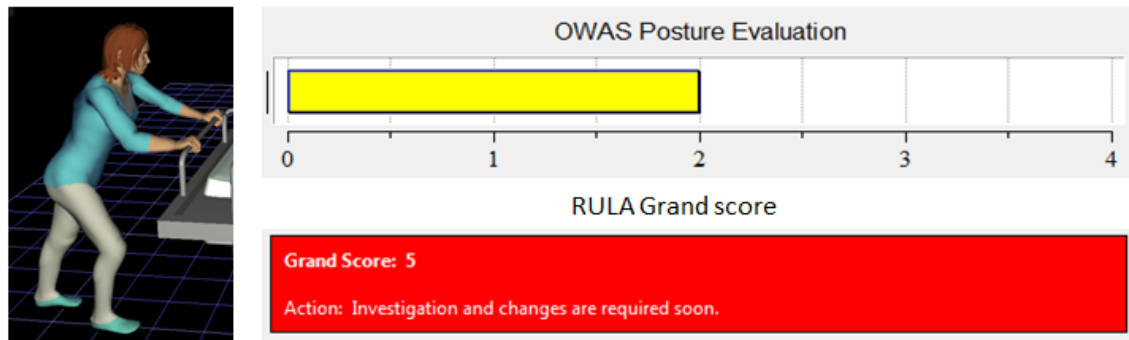


Figure 4. OWAS and RULA posture analysis results for a small female in JACK.

In order to assess the risk of developing musculoskeletal disorders among caregivers when pushing and pulling equipment, Waters, Lloyd, Hernandez, and Nelson (2011) developed the AORN Ergonomic Tool 7. The tool helps to determine when it is necessary to use supportive equipment or when two workers are required to perform a push and pull task. The authors also measured the force necessary to move different types of equipment. Table 2 illustrates the results obtained for hospital beds.

Table 2. Forces required according to the hospital bed (Waters, Lloyd, Hernandez, and Nelson, 2011).

Item	Type of force (N)	Force (N)					Mean force	Max push distance (feet)
		Trial						
		1	2	3	4	5		
Standard Bed, occupied, 300lb	Initial	170	160	167	135	155	157.4	>200
	Sustained	40	50	50	40	60	48	>200
OR bed, occupied, 300 lb	Initial	425	432	445	405	325	406.4	<25
	Sustained	180	180	180			180	<25
Speciality OR bed 300 lb	Initial	365	290	320	305	305	317	<25
	Sustained	140	160	140	115	115	134	<25

Figure 5 illustrates low back analysis results in JACK. A force of 350N (70lbf) was used in the calculations. Typical hospital beds weigh about 200kg and studies have established forces of up to 1200N on carpet floor to move a hospital bed. An initial pushing force of 350N is a conservative estimate which will apply to common vinyl floors and occupied beds; forces for moving empty beds were found to be around 200N on such floors (Daniell et al., 2014).

According to the Ergonomic tool 7, a pushing task involving this force should be performed by two nurses. This is in accordance to the low back analysis, which shows compression forces above the limits established by NIOSH. With the assumption of a 350N pushing force, compression at L4/L5 is beyond 3400N, the action limit for increased risk of low back injury set by NIOSH. There is also a significant flexion moment of close to 200Nm around L4/L5. The low back analysis model in JACK also predicts symmetric muscle tension in the erector spinae of about 1500N. Other trunk muscles however are reported inactive (Figure 5).

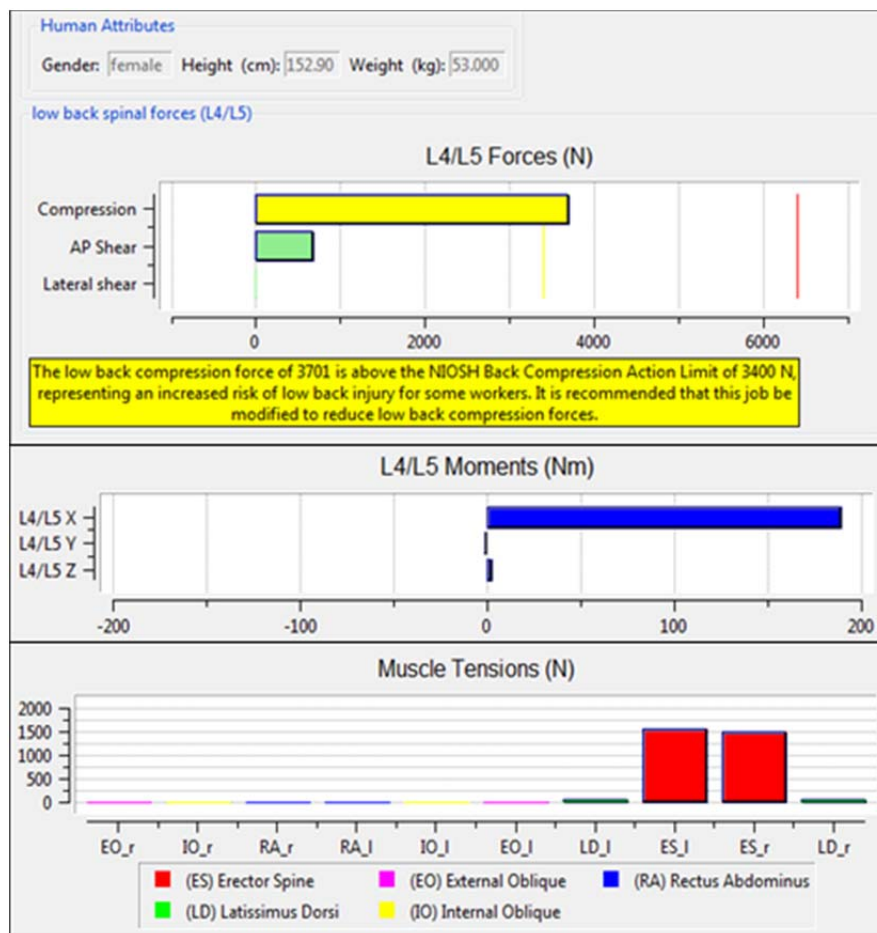


Figure 5. Low back analysis report in JACK, with forces, moments and muscle tensions at L4/L5.

4. Discussion

Health care workers such as nurses experience a high incidence rate of work-related musculoskeletal disorders, with in particular, lower back pain among health careworkers identified as a significant issue with an increased risk of injury when compared to other professions. Over 75% of manual handling injuries in an Australian hospital reported were back injuries. Moreover, health care workers rated moving hospital beds as one of the top physical tasks for complaints of musculoskeletal pains (Daniell et al., 2014). It is therefore important to fully understand the physical strain imposed by moving hospital beds. This can be best achieved through parameter variation in a simulation system. In general, Siemens JACK is well suited for this purpose. The analysis however poses challenges. Given that JACK is not an intrinsically dynamic system, complex interface conditions such as the bed wheel rolling resistance, wheel friction, wheel slip and overall force transmission between the bed and an operator cannot be simulated in the system. Instead, additional methods and external, likely empirical or experimental data are required as input for JACK to provide parameters for the biomechanical ergonomic assessment.

While OWAS and RULA posture evaluation provide some rough insight into postural and related design deficiencies, they assess a static condition and do not consider the problematic dynamic nature of the task. The low back analysis based on NIOSH clearly identifies a critical compression force at L4/L5 beyond established limits. The analysis of muscle tension however contradicts common sense and findings of other studies such as Daniell et al. (2014), where it was found that a large number of muscles are active in hospital bed pushing, and potentially significant contribution to spinal load may stem from internal oblique activity.

Given those limitations, we conclude that a simulated assessment of the biomechanically complex task of pushing a hospital bed remains limited in JACK and can only provide a direction for further research.

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